

Natural Conditions Assessment for Low pH and Dissolved Oxygen in Totopotomoy Creek, Hanover County, Virginia



**Submitted by
Virginia Department of Environmental Quality**

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Executive Summary

This report presents the assessment of whether low pH and dissolved oxygen (DO) in Totopotomoy Creek are due to natural conditions or whether a Total Maximum Daily Load (TMDL) must be performed because of anthropogenic impacts. Totopotomoy Creek is located within Hanover County, Virginia, and is a major tributary of the Pamunkey River, which is a major tributary of the York River. The waterbody identification (WBID) code for Totopotomoy Creek is VAP-F13R. Totopotomoy Creek encompasses a total of approximately 70.98 rivermiles (National Hydrography Dataset (NHD)). Totopotomoy Creek was listed as impaired due to violations in water quality standards for pH. However, violations of the dissolved oxygen (DO) water quality standard were identified during data collection for this report. This report addresses both the pH and DO impairments.

The mainstem of Totopotomoy Creek was listed as impaired on Virginia's 2004 303(d) Total Maximum Daily Load Priority List and Report, and the 2006, 2008, 2010 and draft 305(b) / 303(d) Integrated Reports (VADEQ, 2002, 2004, 2006, 2008, 2010 and draft 2012) due to violations of the State's water quality standard for pH. Violations of the DO water quality standard were identified during data collection for this report. This report evaluates the pH and DO impairments by determining if natural conditions are the cause of the impairment, thus obviating the need for a TMDL.

DEQ monitored 15 stations on Totopotomoy, Opossum, Academy Creeks, Hawes Millrace and Pony Swamp, as well as on one unnamed tributary with dates ranging from February 1999 through December 2011. The pH minimum and maximum values ranged from 5.43 to 7.5 S.U., and DO values ranged from 1.2 to 15.33 mg/L. All 11 pH violations occurred at the original listing station (8-TPT004.37) resulting in a violation rate of 15%. This was the only station with any pH violations. Four stations violated the DO water quality standard more than 10.5% of visits. Totopotomoy Creek will be listed as impaired for DO in the draft 2014 IR Report. Figures E1 and E2 show respective pH concentrations at the listing station 8-TPT004.37 and DO concentrations at 8-TPT006.97.

Figure E1. pH concentrations at Totopotomoy Creek station 8-TPT004.37.

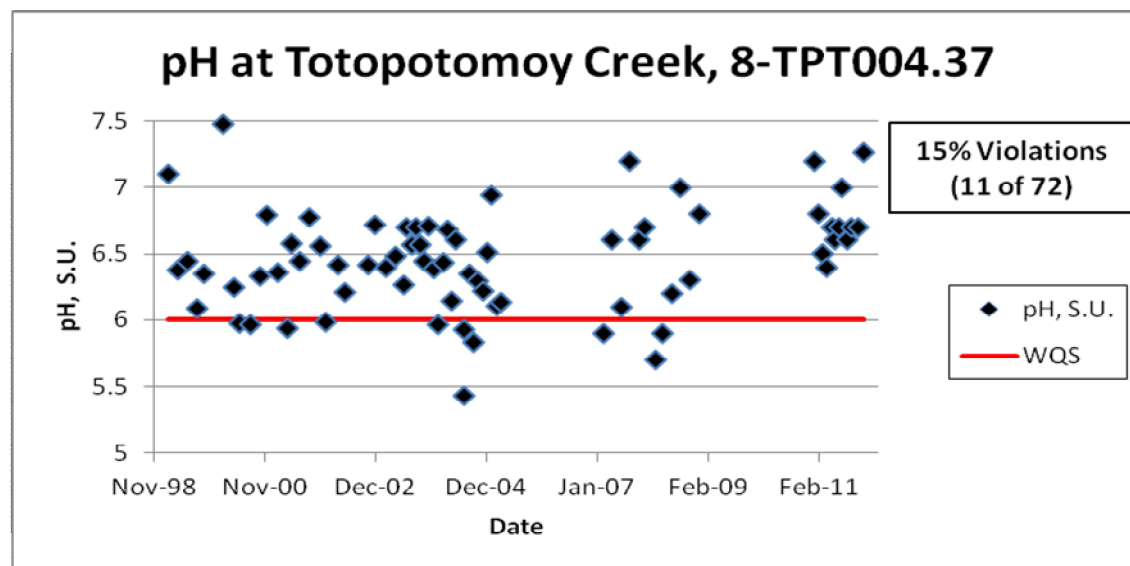
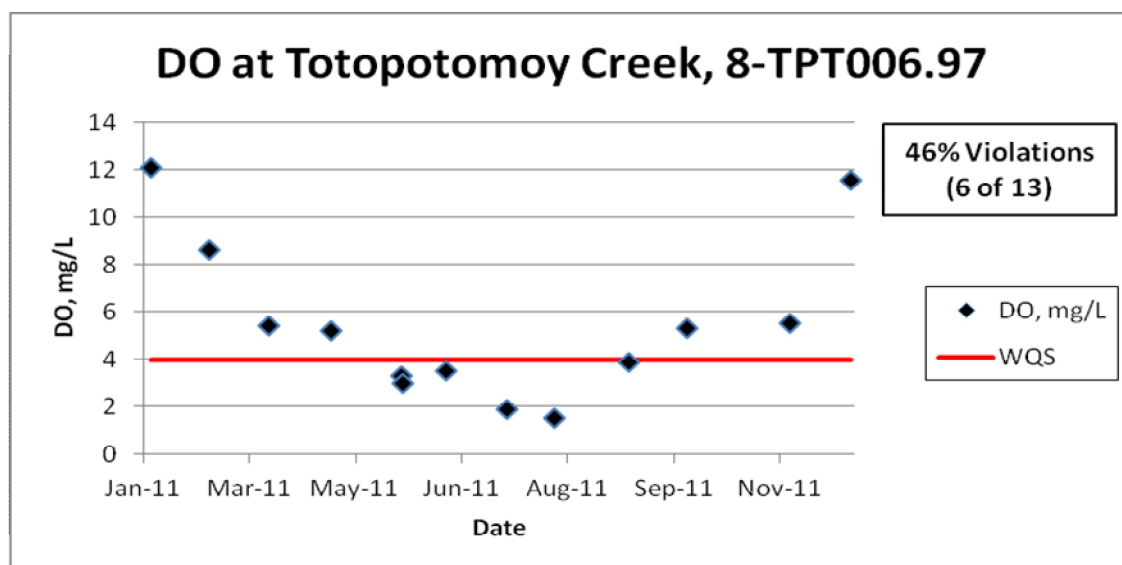


Figure E2. DO concentrations at Totopotomoy Creek station 8-TPT006.97.



According to Virginia Water Quality Standards (9 VAC 25-260-10A), "all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."

As indicated above, Totopotomoy Creek must support all designated uses and meet all applicable criteria. If the waterbody violates the instantaneous DO water quality standard of 4.0 mg/l or pH values are less than 6.0 or greater than 9.0 in more than 10.5 percent of samples, the waterbody is classified as impaired and natural conditions must be determined or a TMDL must be developed and implemented to bring the waterbody into compliance with the water quality criterion.

In 2003 VADEQ proposed a methodology for determining whether low DO or pH originates from natural or anthropogenic sources, adapted from "Methodology for Assessing Natural Dissolved Oxygen and pH Impairments: Application to the Appomattox River Watershed, Virginia" (MapTech 2003).

The level of dissolved oxygen in a water body is determined by a balance between oxygen-depleting processes (e.g., decomposition and respiration) and oxygen restoring processes (e.g., aeration and photosynthesis). Certain natural conditions promote a situation where oxygen-restoring processes are not sufficient to overcome the oxygen-depleting processes. Conditions that would typically be associated with naturally low DO include slow-moving, ripple-less waters where the bacterial decay of organic matter depletes DO at a faster rate than it can be replenished. Indicators of these conditions include low slope, the presence of swamps or wetlands. These conditions often also produce low pH due to organic acids (tannins, humic and fulvic substances) produced in the decay process. These situations can be compounded by anthropogenic activities that contribute excessive nutrients or readily available organic matter to these systems.

The general approach to determine if DO and pH impairments in free-flowing streams are due to natural conditions is to assess a series of water quality and hydrologic criteria to determine the likelihood of an anthropogenic source. A logical 4-step process for identifying natural conditions that result in low DO and/or low pH levels and for determining the likelihood of anthropogenic impacts is described below. DEQ staff use this approach to implement State Water Control Law 9 VAC 25-260-55, Implementation Procedure for Dissolved Oxygen Criteria in Waters Naturally Low in Dissolved Oxygen.

Before implementing this procedure, all DO and pH data should be screened for flows less than the 7Q10. DO and pH data collected on days when flow was < 7Q10 should be eliminated from the data set and the violation rate recalculated accordingly.

Natural Conditions Assessment for Totopotomoy Creek

- Step 1. Determine slope and appearance (presence of wetlands).
- Step 2. Determine nutrient levels and compare with USGS background concentrations.
- Step 3. Determine degree of seasonal fluctuation (for DO only).
- Step 4. Determine anthropogenic impacts from permitted dischargers and land use.

There were no Totopotomoy Creek pH and DO data points collected on dates when Totopotomoy Creek flows were below 7Q10, therefore no datapoints were removed.

The percent slope of Totopotomoy Creek was 0.18% slope. This is lower than the defined low slope criteria of 0.50%. Decomposition of the large inputs of decaying vegetation from areas of forested land with swamps and heavy tree canopy throughout the watersheds increase oxygen demand and lower DO as they decay, as well as contribute to the low pH by creation of natural weak organic acids (tannic, humic and fulvic acids) during decomposition of the decaying vegetation. These are not considered anthropogenic impacts. Percent slope was not calculated for any tributaries to Totopotomoy Creek because none held pH nor DO standard violations, except for one station with one violation out of 13 visits immediately below the dam of a residential development pond, and the violation was obtained during low flow.

The average total nitrogen (TN), nitrate and total phosphorus (TP) concentrations are below the USGS (1999) national background nutrient concentrations in streams from undeveloped areas with levels of TN < 1.0 mg/l, nitrate < 0.6 mg/l and TP < 0.1 mg/l. These low nutrient levels are not indicative of human impact.

Totopotomoy Creek exhibits natural seasonal DO fluctuation due to the inverse relationship between water temperature and DO.

There are no active permitted point source dischargers in the Totopotomoy Creek watershed.

The average annual rainfall is 42 inches. The watershed is approximately 19570 acres (30.58 mi²) in size and is predominately forested (47 percent). Agriculture comprises 22 percent of the watershed, with 15 percent cropland and 7 percent pasture/hayland. Urban areas compose approximately 18 percent of the land base, located mostly in the headwaters. The remaining 13 percent of the watershed is comprised of 4 percent other grasses and 9 percent wetlands and open water. There are large areas of wetlands in the lower half of the watershed, and also in large pockets in the upper more urban portion of the watershed. Land use was not considered to have significantly impacted the swampwater conditions of Totopotomoy Creek.

Based on the above information, a change in the water quality standards classification to Class VII Swampwater due to natural conditions, rather than a TMDL, is indicated for the mainstem of Totopotomoy Creek located in waterbody identification codes (WBID) VAP-F13R, for a total of 17.61 rivermiles. Even though there were two stations that did not have standard violations in the upper half of the watershed, DEQ decided to include this 3 mile segment in the Class VII designation because the lowest pH was at the standard, and the lowest DO was only 0.3 mg/l above the standard. This 3 mile segment probably experiences pH and DO below the water quality standards. If there is a 305(b)/303(d) assessment prior to the reclassification, Totopotomoy Creek will be assessed as Category 4C, Impaired due to natural condition, no TMDL needed.

DEQ performed the assessment of the Totopotomoy Creek low DO and low pH natural condition in lieu of a TMDL. Therefore neither a TMDL Technical Advisory Committee (TAC) meeting nor a public meeting was involved. Public participation will occur during the next water quality standards triennial review process.

1. Introduction

Totopotomoy Creek is located within Hanover County, Virginia, and is a major tributary of the Pamunkey River, a major tributary of the York River. There are 70.98 total stream miles in the Totopotomoy Creek

watershed (National Hydrography Dataset (NHD)) using GIS. Totopotomoy Creek is fed by tributaries Opossum Creek, Strawhorn Creek and its tributary Academy Creek, Hawes Millrace, Pony Swamp and four perennial unnamed tributaries. The impaired segment for low pH totals 10.26 miles of mainstem Totopotomoy Creek from the confluence with Strawhorn Creek to the mouth. Totopotomoy Creek generally flow east from the headwaters near Poindexters, VA, to the confluence with the Pamunkey River approximately 3 miles upstream of the Rt. 360 bridge. The watershed totals approximately 30.58 mi². There is one continuous flow gaging station on Totopotomoy Creek, Totopotomoy Creek near Studley, VA, 01673550, with a drainage area of 25.5 mi² and data from 1977 to 2012.

2. Physical Settings

2.1. Listed Water Bodies

The mainstem of Totopotomoy Creek was listed as impaired on Virginia's 2004 303(d) Total Maximum Daily Load Priority List and Report, and the 2006, 2008, 2010 and draft 305(b) / 303(d) Integrated Reports (VADEQ, 2002, 2004, 2006, 2008, 2010 and draft 2012) due to violations of the State's water quality standard for pH. This report evaluates the pH impairment by determining if natural conditions are the cause of the impairment, thus obviating the need for a TMDL. The waterbody identification code (WBID, Virginia Hydrologic Unit) for non-tidal Totopotomoy Creek is VAP-F13R.

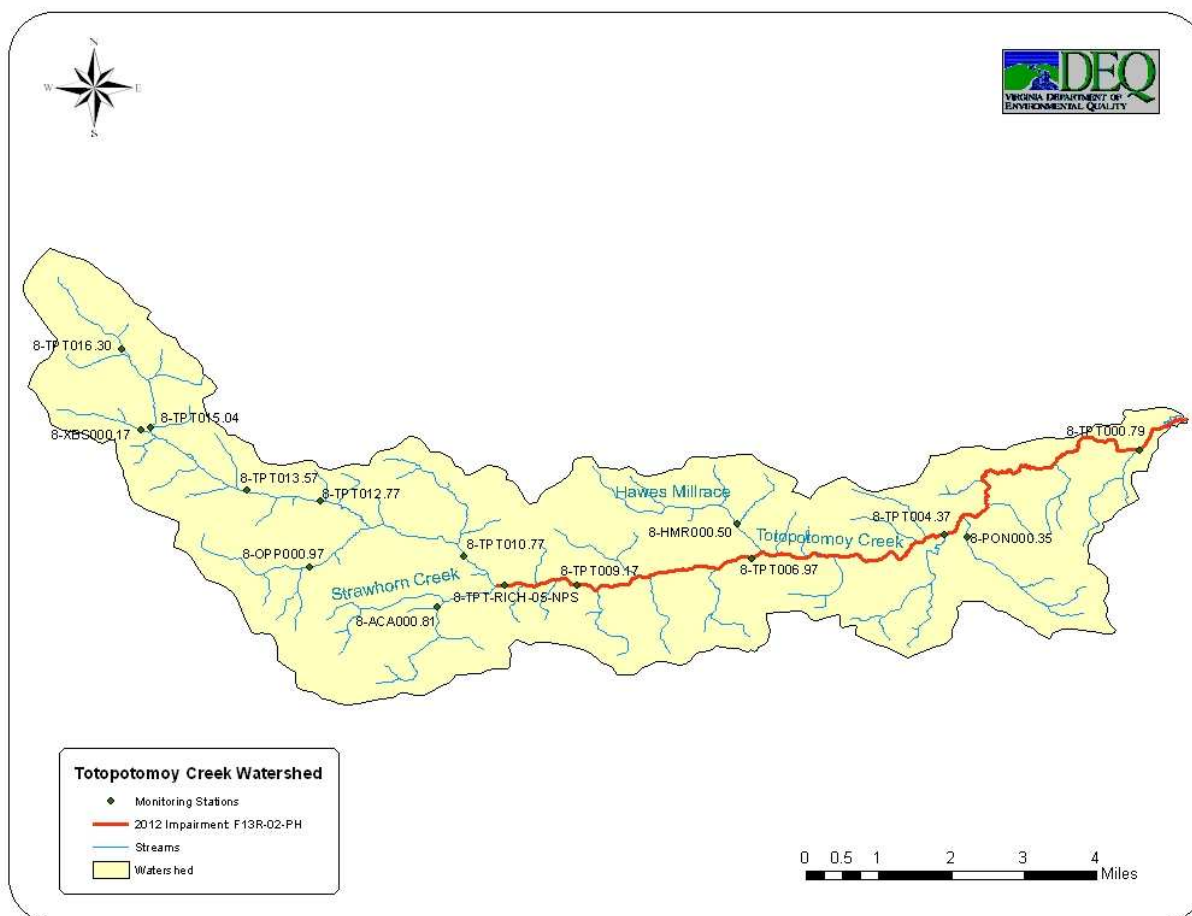
2.2. Watershed

2.2.1. General Description

Totopotomoy Creek generally flow east from the headwaters near Poindexters, VA, to the confluence with the Pamunkey River approximately 3 miles upstream of the Rt. 360 bridge. The watershed totals approximately 30.58 mi². There is one continuous flow gaging station on Totopotomoy Creek, Totopotomoy Creek near Studley, VA, 01673550, with a drainage area of 25.5 mi² and data from 1977 to 2012. See Figure 1 for a map of the watershed including 15 monitoring stations.

Figure 1. The Totopotomoy Creek watershed map and associated monitoring stations.

Natural Conditions Assessment for Totopotomoy Creek



2.2.2. Geology, Climate, Land Use

Geology and Soils

The impaired segment of Totopotomoy Creek is within the Atlantic Coastal Plain physiographic region. The Atlantic Coastal Plain is the easternmost of Virginia's physiographic provinces. The Atlantic Coastal Plain extends from New Jersey to Florida, and includes all of Virginia east of the Fall Line. The Fall Line is the easternmost extent of rocky river rapids, the point at which east-flowing rivers cross from the hard, igneous and metamorphic rocks of the Piedmont to the relatively soft, unconsolidated strata of the Coastal Plain. The Coastal Plain is underlain by layers of Cretaceous and younger clay, sand, and gravel that dip gently eastward. These layers were deposited by rivers carrying sediment from the eroding Appalachian Mountains to the west. As the sea level rose and fell, fossiliferous marine deposits were interlayered with fluvial, estuarine, and beach strata. The youngest deposits of the Coastal Plain are sand, silt and mud presently being deposited in our bays and along our beaches (http://www.dcr.virginia.gov/natural_heritage/documents/overviewPhysiography_vegetation.pdf).

Soils for the Totopotomoy Creek watershed were documented utilizing the VA State Soil Geographic Database (STATSGO). Three general soil types were identified using in this database. Descriptions of these soil series were derived from queries to the USDA Natural Resources Conservation Service (NRCS) Official Soil Series Description web site (<http://soils.usda.gov/technical/classification/osd/index.html>). Figure 2 shows the location of these general soil types in the watershed.

Soils of the Emporia-Johnston-Kenansville-Remlik-Rumford-Slagle-Suffolk-Tomotley (VA027) series are very deep to deep, and vary between well drained to poorly drained with moderately slow or slow permeability.

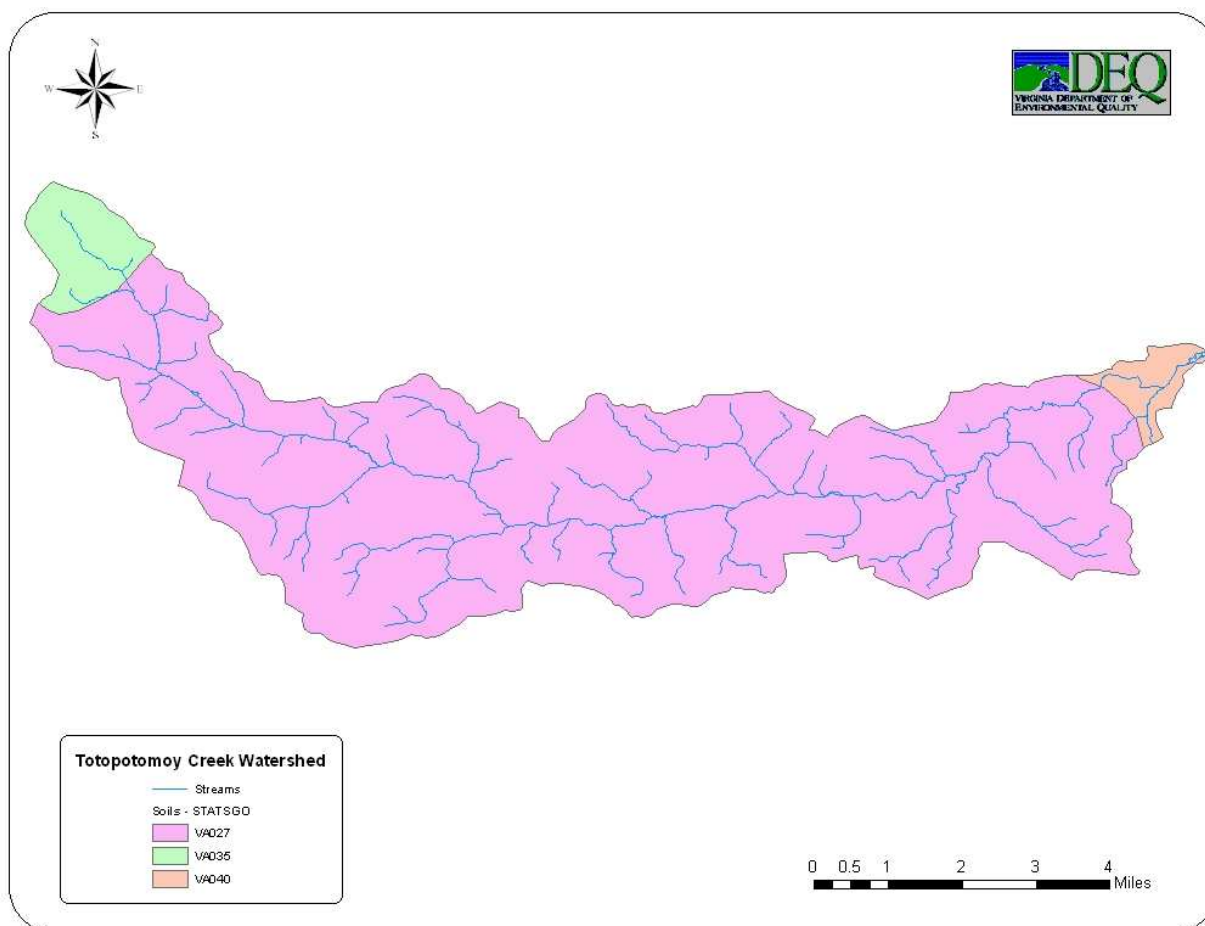
Natural Conditions Assessment for Totopotomoy Creek

They formed in moderately fine-textured stratified fluvial and marine sediments on the upper Coastal Plain and stream terraces.

The soils of the Craven-Mattaponi-Lenoir-Coxville (VA035) series are very deep in which the drainage ranges from somewhat poor to well drained and the permeability is typically slow to moderately slow. The soils formed in flats or depressions from the lower to upper Coastal Plain and Piedmont Physiographic Provinces of the Atlantic Coast, in which the parent materials consists of fluvial and marine sediments.

Soils of the Bojac-Pamunkey-Munden-Angie-Augusta-Molena-Argent series (VA040) are very deep and range from excessively drained to poorly drained conditions. Permeability is moderately rapid to slow. This series, located on stream terraces and uplands, is composed of loamy and sandy fluvial and marine Coastal Plain sediments.

Figure 2. Soil Characteristics of the Totopotomoy Creek Watershed.



Climate

The climate summary for Totopotomoy Creek comes from a weather station located in Ashland, VA (440327) with a period of record from 1893 to 2011. The average annual maximum and minimum temperatures (°F) at the weather station are 67.7 and 45.6 and the annual rainfall (inches) is 42.23 (Table 1) (Southeast Regional Climate Center, http://www.sercc.com/climateinfo/historical/historical_va.html).

Table 1. Climate summary for Ashland, Virginia (440327).

Natural Conditions Assessment for Totopotomoy Creek

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	46.3	49.4	59.0	69.3	76.6	83.2	86.9	85.4	79.6	69.2	59.2	48.8	67.7
Average Min. Temperature (F)	26.0	27.5	34.8	43.6	53.1	61.6	66.2	65.0	58.2	46.2	36.1	28.4	45.6
Average Total Precipitation (in.)	3.16	2.83	3.69	3.24	3.80	3.68	4.26	4.35	3.62	3.27	2.96	3.36	42.23

Land Use

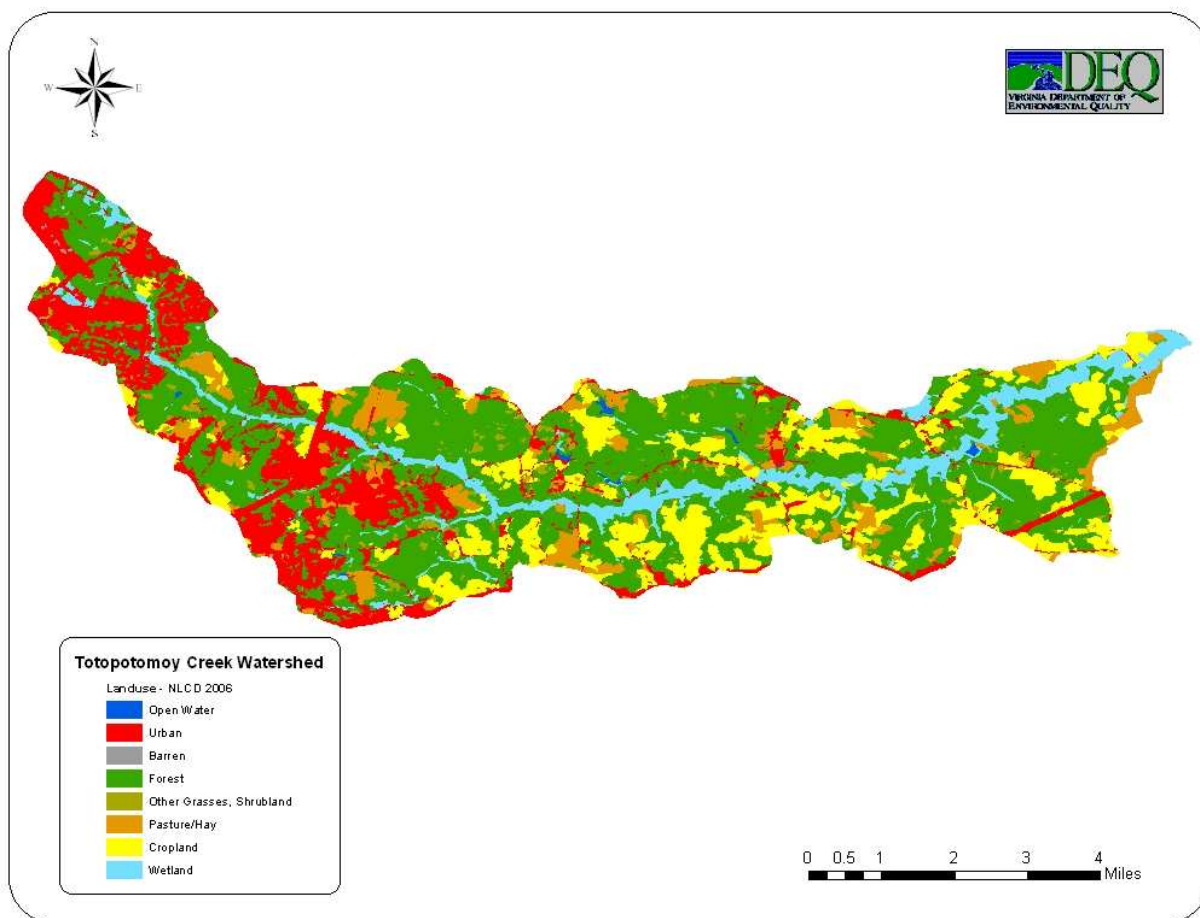
The Totopotomoy Creek watershed extends from approximately Poindexters, VA, to the Pamunkey River. It is approximately 12 miles long and 2.5 miles wide. The watershed is approximately 19570 acres (30.58 mi²) in size and is predominately forested (47 percent). Agriculture comprises 22 percent of the watershed, with 15 percent cropland and 7 percent pasture/hayland. Urban areas compose approximately 18 percent of the land base. The remaining 13 percent of the watershed is comprised of 4 percent other grasses and 9 percent wetlands and open water. Land use percentages, square miles and acres are affected by rounding. Land use is described in Table 2.

A map of the distribution of land use in the watershed (Figure 3) shows that urban land use is concentrated in the upstream third of the watershed in the Poindexters (Rts. 656 and 637) and Atlee/Pearsons Corner (Rt. 301) areas. Wetlands are concentrated along the mainstem of Totopotomoy from Strawhorn Creek to the mouth.

Table 2. Land Use in the Totopotomoy Creek Watershed

Land Use Type	Acres	Square Miles	Percent
Open Water	51	0.08	0.3%
Urban	3616	5.65	18.5%
Barren	13	0.02	0.1%
Forest	9171	14.33	46.9%
Pasture/Hay	1408	2.20	7.2%
Cropland	2867	4.48	14.7%
Other Grasses	781	1.22	4.0%
Wetland	1658	2.59	8.5%
Totals:	19570	30.58	100%
Land Use Type	Acres	Square Miles	Percent

Figure 3. Land Use in the Totopotomoy Creek Watershed



3. Description of Water Quality Problem/Impairment

The mainstem of Totopotomoy Creek was listed as impaired on Virginia's 2004 303(d) Total Maximum Daily Load Priority List and Report, and the 2006, 2008, 2010 and draft 305(b) / 303(d) Integrated Reports (VADEQ, 2002, 2004, 2006, 2008, 2010 and draft 2012) due to violations of the State's water quality standard for pH. This report evaluates the pH impairment by determining if natural conditions are the cause of the impairment, thus obviating the need for a TMDL.

DEQ monitored 15 stations on Totopotomoy, Opossum, Academy Creeks, Hawes Millrace and Pony Swamp, as well as on one unnamed tributary (see Figure 1) with dates ranging from February 1999 through December 2011. The pH minimum and maximum values ranged from 5.43 to 7.5 S.U., and DO values ranged from 1.2 to 15.33 mg/L. All 11 pH violations occurred at the original listing station (8-TPT004.37) resulting in a violation rate of 15%. This was the only station with any pH violations. Four stations violated the DO water quality standard more than 10.5% of visits. Totopotomoy Creek will be listed as impaired for DO in the draft 2014 IR Report. Station 8-TPT006.97 had 46% violations, 8-TPT009.17 had 31% violations, 8-TPT013.57 had 23% violations and 8-TPT016.30 had 15% violations of the DO standard. The National Battlefield Park sampled station 8-TPT-RICH-05-NPS. All results are summarized in Table 3.

Natural Conditions Assessment for Totopotomoy Creek

Table 3. pH and DO data collected by DEQ from 15 stations on Totopotomoy Creek.

Station	Sample Period	Number of Samples		SU		mg/l		Number of Violations	
		pH	DO	Average pH	Min-Max pH	Average DO	Min-Max DO	pH	DO
8-TPT004.37	2/8/1999 to 12/21/2011	72	72	6.46	5.43–7.48	9.33	5.07–15.33	11	0
8-TPT000.79	1/25/2011 to 12/21/2011	13	13	6.82	6.1 – 7.3	8.57	5.8 – 13.9	0	0
8-TPT006.97	1/25/2011 to 12/21/2011	13	13	6.54	6.1 – 7.3	5.44	1.5 – 12.1	0	6
8-TPT009.17	1/25/2011 to 12/21/2011	13	13	6.61	6.1 – 7.5	5.71	2.0 – 13.0	0	4
8-TPT010.77	1/25/2011 to 12/21/2011	13	13	6.75	6.2 – 7.43	8.27	5.6 – 13.9	0	0
8-TPT012.77	1/25/2011 to 12/21/2011	13	13	6.59	6.0 – 7.2	7.45	4.3 – 14.1	0	0
8-TPT013.57	1/25/2011 to 12/21/2011	13	13	6.60	6.2 – 7.29	6.58	3.7 – 12.6	0	3
8-TPT015.04	1/25/2011 to 12/21/2011	13	13	6.55	6.1 – 7.17	6.67	2.1 – 13.1	0	1
8-TPT016.30	1/25/2011 to 12/21/2011	13	13	6.56	6.3 – 7.07	7.28	1.2 – 13.1	0	2
8-ACA000.81	1/25/2011 to 12/21/2011	13	13	6.56	6.0 – 6.9	8.87	6.8 – 13.1	0	0
8-HMR000.50	1/25/2011 to 12/21/2011	13	13	6.64	6.1 – 7.2	9.38	7.1 – 13.8	0	0
8-OPP000.97	1/25/2011 to 12/21/2011	13	13	6.56	6.2 – 6.8	8.50	6.5 – 12.3	0	0
8-PON000.35	1/25/2011 to 12/21/2011	13	13	6.73	6.0 – 7.4	9.65	7.5 – 13.84	0	0
8-XBS000.17	1/25/2011 to 12/21/2011	13	13	6.87	6.4 – 7.37	7.69	3.1 – 12.8	0	1
8-TPT-RICH-05-NPS	7/29/2009 to 11/3/2010	4	4	6.56	6.37–6.75	6.39	5.28-8.21	0	0

Time series graphs of all pH and DO data collected at the original listing station, Totopotomoy Creek at station 8-TPT004.37, showed the pH ranged from 5.43 to 7.48 S.U. (Figure 4). The horizontal red line at the pH = 6.0 mark represents the minimum water quality standard in Figure 4. The data points below the pH = 6.0 line are violations of the water quality standard in Figure 4. The horizontal red line at the DO = 4.0 mark represents the minimum water quality standard in Figure 5. The data points below the DO = 4.0 line are violations of the water quality standard in Figure 5.

Figure 4. Time series of pH at Totopotomoy Creek station 8-TPT004.37.

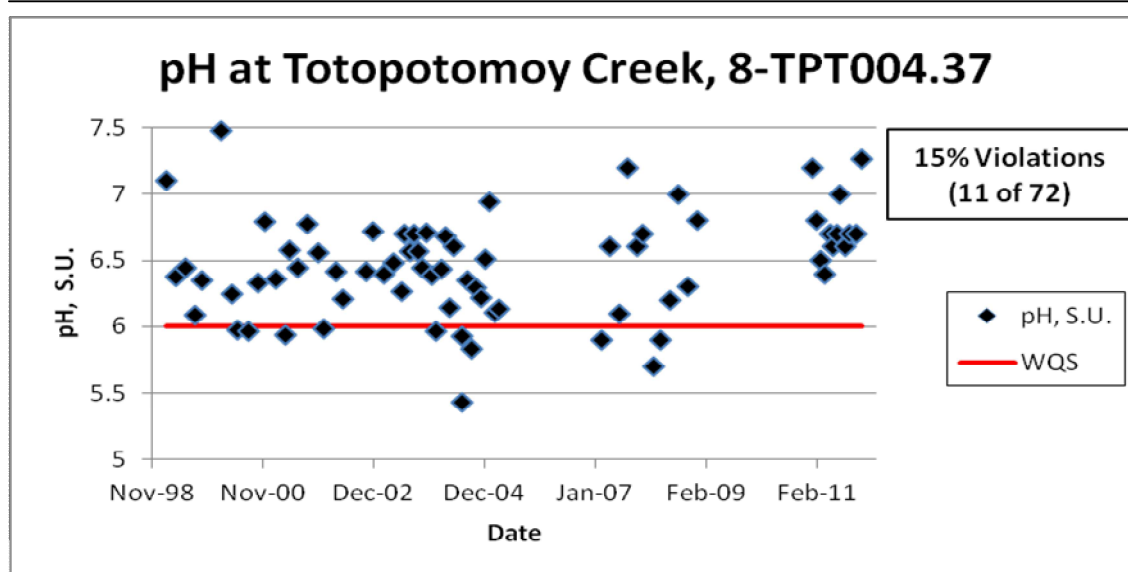
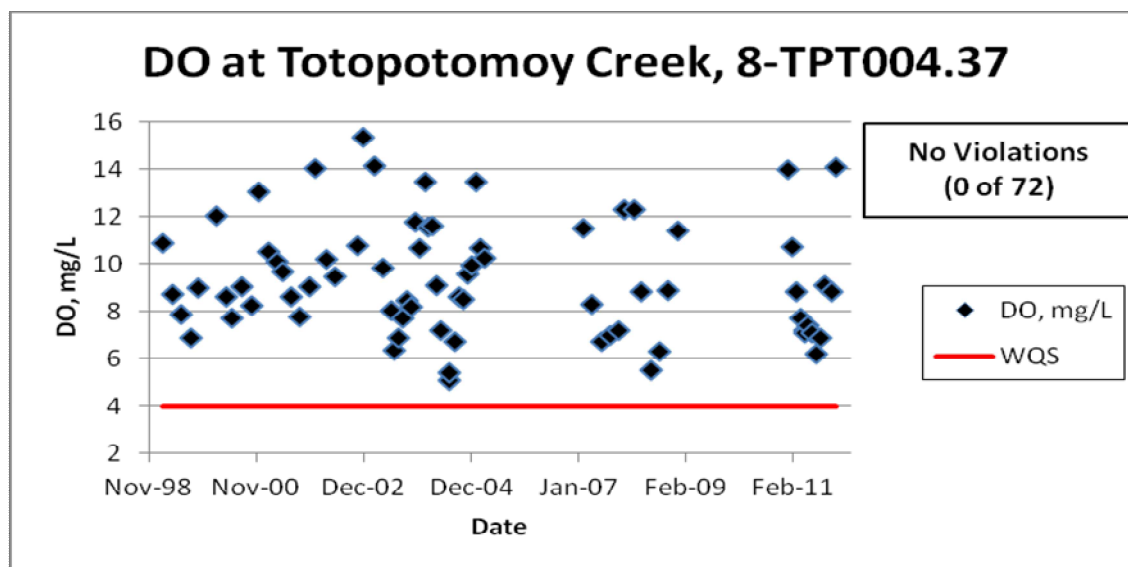


Figure 5. Time series of DO at Totopotomoy Creek station 8-TPT004.37.



3.1. Associated pH and DO of Totopotomoy Creek

DEQ also monitored pH and DO data at 14 other stations on Totopotomoy Creek and tributaries for the assessment of low pH and DO due to the natural conditions. No other associated stations exceeded the water quality standards for pH of 6.0 S. U., although 8 other stations had minimum pH values of 6.0 or 6.1 S.U. Four other stations violated the DO water quality standard more than 10% of visits (8-TPT006.97, 8-TPT009.17, 8-TPT013.57 and 8-TPT016.30). See Figures 6 through 9 for time series of DO at associated Totopotomoy Creek stations with more than 10% DO violations. Two stations had no DO standard violations, 8-TPT010.77 and 8-TPT012.77. These represent stream conditions for approximately 3 miles of Totopotomoy Creek from slightly above Rt. 301 to the confluence with Strawhorn Creek.

Figure 6. Time series of DO at Totopotomoy Creek station 8-TPT006.97.

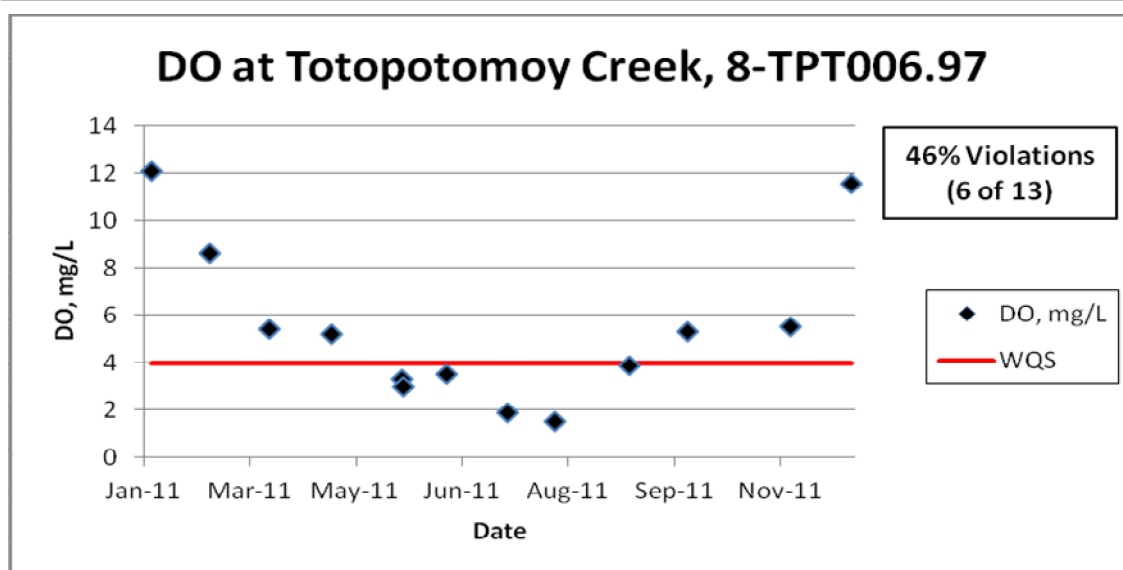


Figure 7. Time series of DO at Totopotomoy Creek station 8-TPT009.17.

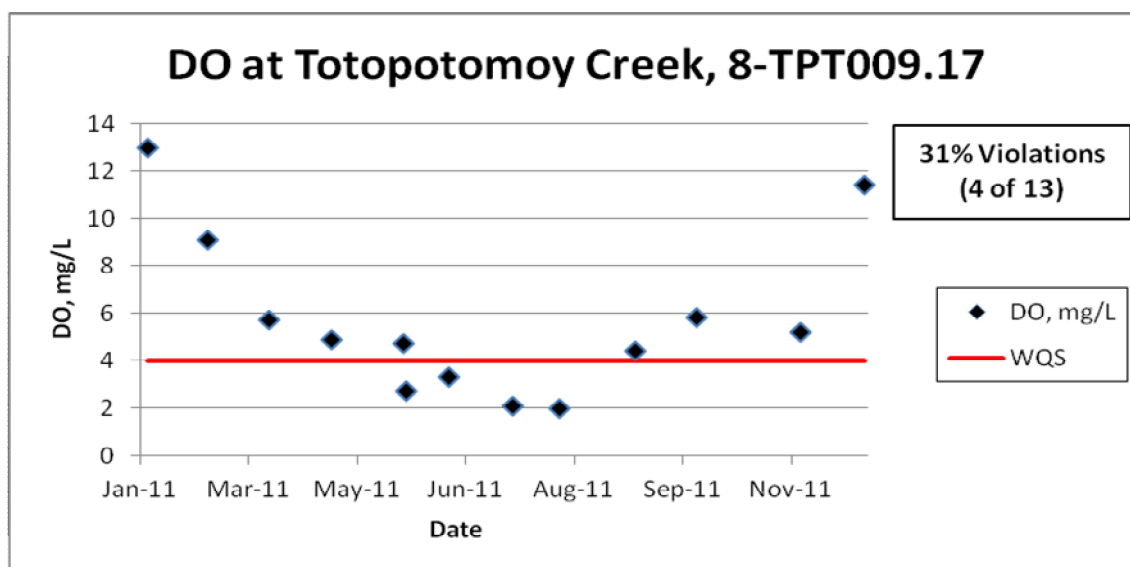


Figure 8. Time series of DO at Totopotomoy Creek station 8-TPT013.57.

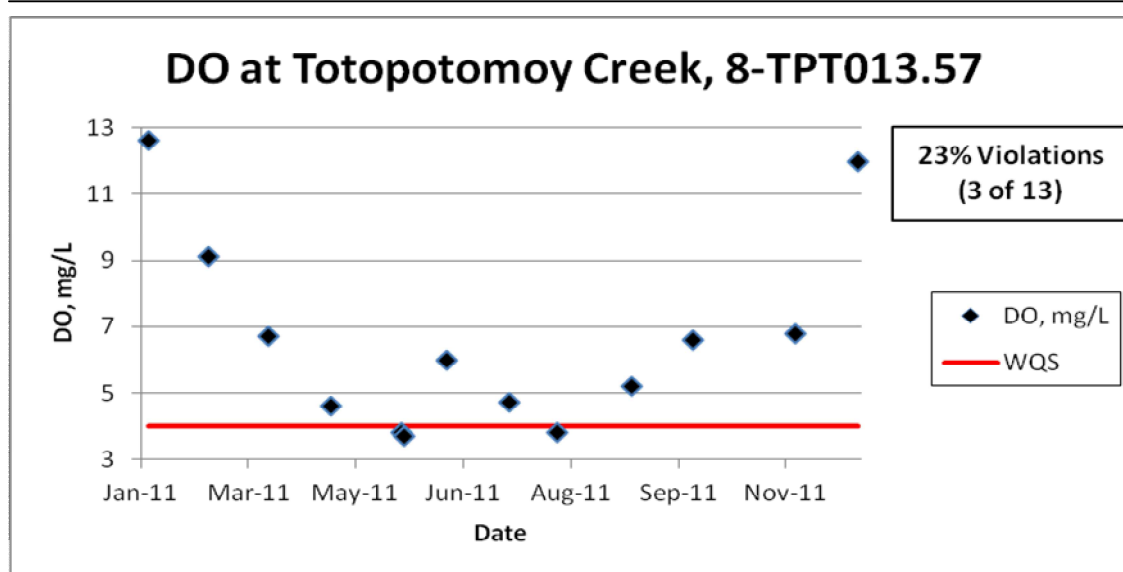
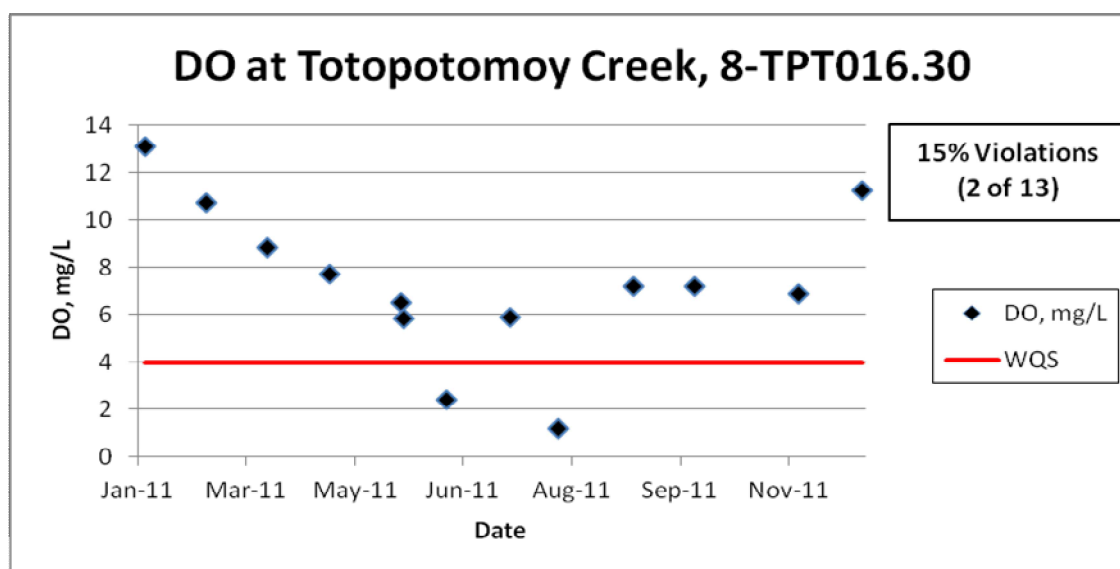


Figure 9. Time series of DO at Totopotomoy Creek station 8-TPT016.30.



4. Water Quality Standard

According to Virginia Water Quality Standards (9 VAC 25-260-5), the term “water quality standards means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.).”

As stated above, Virginia water quality standards consist of a designated use or uses and water quality criteria. These two parts of the applicable water quality standard are presented in the sections that follow.

4.1. Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10A), “all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish).”

As stated above, Totopotomoy Creek must support all designated uses and meet all applicable criteria.

4.2. Applicable Water Quality Criteria

The applicable water quality criteria for DO and pH in the Totopotomoy Creek watershed are an instantaneous minimum DO of 4.0 mg/l and pH from 6.0 SU to 9.0 SU, as in Table 4.

Table 4. Applicable water quality standards		
Parameter	Minimum, mg/l	Maximum, mg/l
pH	6.0	9.0
DO	4.0	-

If the waterbody exceeds the criterion listed above in more than 10.5 percent of samples, the waterbody is classified as impaired and natural conditions must be determined or a TMDL must be developed and implemented to bring the waterbody into compliance with the water quality criterion.

5. Assessment of Natural Conditions Affecting low DO - Process for determining if DO and pH impairments in free-flowing streams are due to natural conditions.

The level of dissolved oxygen in a water body is determined by a balance between oxygen-depleting processes (e.g., decomposition and respiration) and oxygen-restoring processes (e.g., aeration and photosynthesis). Certain natural conditions promote a situation where oxygen-restoring processes are not sufficient to overcome the oxygen-depleting processes. The level of pH in a water body is determined by a balance between organic acids produced by decay of vegetative material, and buffering capacity. Conditions in a stream that would typically be associated with naturally low DO and pH include slow-moving, ripple-less waters or wetlands where the decay of organic matter produces organic acids. These situations can be compounded by anthropogenic activities that contribute excessive nutrients or readily available organic matter to these systems. The general approach to determine if DO and pH impairments in streams are due to natural conditions is to assess a series of water quality and hydrologic criteria to determine the likelihood of an anthropogenic source. A logical 4-step process for identifying natural conditions that result in low DO and/or pH levels and for determining the likelihood of anthropogenic impacts that will exacerbate the natural condition is described below.

- Step 1. Determine slope and appearance.
- Step 2. Determine nutrient levels.
- Step 3. Determine degree of seasonal fluctuation (for DO only).
- Step 4. Determine anthropogenic impacts.

The results from this methodology (or process or approach) will be used to determine if the stream should be re-classified as Class VII Swamp Waters. Each step is described in detail below.

Procedure for Natural Condition Assessment of low pH and low DO in Virginia Streams

Prepared by Virginia Department of Environmental Quality
October 2004

I. INTRODUCTION

Virginia's list of impaired waters currently shows many waters not supporting the aquatic life use due to exceedances of pH and/or DO criteria that are designed to protect aquatic life in Class III waters. However, there is reason to believe that most of these streams or stream segments have been mis-classified and should more appropriately be classified as Class VII, Swamp Waters. This document presents a procedure for assessing if natural conditions are the cause of the low pH and/or low DO levels in a given stream or stream segment.

The level of dissolved oxygen (DO) in a water body is determined by a balance between oxygen-depleting processes (e.g., decomposition and respiration) and oxygen-restoring processes (e.g., aeration and photosynthesis). Certain natural conditions promote a situation where oxygen-restoring processes are not sufficient to overcome the oxygen-depleting processes. The level of acidity as registered by pH in a water body is determined by a balance between organic acids produced by decay of vegetative material, and buffering capacity.

Conditions in a stream that would typically be associated with naturally low DO and/or naturally low pH include slow-moving, ripple-less waters. In such waters, the decay of organic matter depletes DO at a faster rate than it can be replenished and produces organic acids (tannins, humic and fulvic substances). These situations can be compounded by anthropogenic activities that contribute excessive nutrients or readily available organic matter to these systems.

The general approach to determine if DO and pH impairments in streams are due to natural conditions is to assess a series of water quality and hydrologic criteria to determine the likelihood of an anthropogenic source. A logical 4-step process for identifying natural conditions that result in low DO and/or pH levels and for determining the likelihood of anthropogenic impacts that will exacerbate the natural condition is described below. DEQ

staff is proposing to use this approach to implement State Water Control Law 9 VAC 25-260-55, Implementation Procedure for Dissolved Oxygen Criteria in Waters Naturally Low in Dissolved Oxygen.

Waters that are shown to have naturally low DO and pH levels will be re-classified as Class VII, Swamp Waters, with the associated pH criterion of 4.3 to 9.0 SU. An associated DO criterion is currently being developed from swamp water data. A TMDL is not needed for these waters. An assessment category of 4C will be assigned until the waterbody has been re-classified.

II. NATURAL CONDITION ASSESSMENT

Following a description of the watershed (including geology, soils, climate, and land use), a description of the DO and/or pH water quality problem (including a data summary, time series and monthly data distributions), and a description of the water quality criteria that were the basis for the impairment determination, the available information should be evaluated in four steps.

Step 1. Determine appearance and flow/slope.

Streams or stream segments that have naturally low DO (< 4 mg/L) and low pH (< 6 SU) are characterized by very low slopes and low velocity flows (flat water with low reaeration rates). Decaying vegetation in such swampy waters provides large inputs of plant material that consumes oxygen as it decays. The decaying vegetation in swamp water also produces acids and decreases pH. Plant materials contain polyphenols such as tannin and lignin. Polyphenols and partially degraded polyphenols build up in the form of tannic acids, humic acids, and fulvic acids that are highly colored. The trees of swamps have higher polyphenolic content than the soft-stemmed vegetation of marshes. Swamp streams (blackwater) are therefore more highly colored and more acidic than marsh streams.

Appearance and flow velocity (or slope if flow velocity is not available) must be identified for each stream or stream segment to be assessed for natural conditions and potential re-classification as Class VII swamp water. This can be done through maps, photos, field measurements or other appropriate means.

Step 2. Determine nutrient levels.

Excessive nutrients can cause a decrease in DO in relatively slow moving systems, where aeration is low. High nutrient levels are an indication of anthropogenic inputs of nitrogen, phosphorus, and possibly organic matter. Nutrient input can stimulate plant growth, and the resulting die-off and decay of excessive plankton or macrophytes can decrease DO levels.

USGS (1999) estimated national background nutrient concentrations in streams and groundwater from undeveloped areas. Average nitrate background concentrations are less than 0.6 mg/L for streams, average total nitrogen (TN) background concentrations are less than 1.0 mg/L, and average background concentrations of total phosphorus (TP) are less than 0.1 mg/L.

Nutrient levels must be documented for each stream or stream segment to be assessed for natural conditions and potential re-classification as Class VII swamp water. Streams with average concentrations of nutrients greater than the national background concentrations should be further evaluated for potential impacts from anthropogenic sources.

Step 3. Determine degree of seasonal fluctuation (for DO only).

Anthropogenic impacts on DO will likely disrupt the typical seasonal fluctuation seen in the DO concentrations of wetland streams. Seasonal analyses should be conducted for each potential Class VII stream or stream segment to verify that DO is depressed in the summer months and recovers during the winter, as would be expected in natural systems. A weak seasonal pattern could indicate that human inputs from point or nonpoint sources are impacting the seasonal cycle.

Step 4. Determine anthropogenic impacts.

Every effort should be made to identify human impacts that could exacerbate the naturally low DO and/or pH. For example, point sources should be identified and DMR data analyzed to determine if there is any impact on the stream DO or pH concentrations. Land use analysis can also be a valuable tool for identifying potential human impacts.

Lastly, a discussion of acid rain impacts should be included for low pH waters. The format of this discussion can be based either on the process used for the recent Class VII classification of several streams in the Blackwater watershed of the Chowan Basin (letter from DEQ to EPA, 14 October 2003). An alternative is a prototype regional stream comparison developed for Fourmile Creek, White Oak Swamp, Matadequin Creek and Mechumps Creek (all east of the fall line). The example analysis under IV in this document, or the example report prepared for Fourmile Creek, illustrate this approach. For streams west of the fall line, a regional stream comparison for 2004 analyses encompasses Winticomack, Winterpock, and Chickahominy Rivers.

7Q10 Data Screen

If the data warrant it, a data screen should be performed to ensure that the impairment was identified based on valid data. All DO or pH data that violate water quality standards should be screened for flows less than the 7Q10. Data collected on days when flow was < 7Q10 should be eliminated from the data set and the violation rate recalculated accordingly. Only those waters with violation rates determined days with flows > or = 7Q10 flows should be classified as impaired.

In some cases, data were collected when flow was 0 cfs. If the 7Q10 is identified as 0 cfs as well, all data collected under 0 cfs flow would need to be considered in the water quality assessment. In those cases, the impairment should be classified as 4C, impaired due to natural conditions, no TMDL needed. However, a reclassification to Class VII may not always be appropriate.

III. NATURAL CONDITION CONCLUSION MATRIX

The following decision process should be applied for determining whether low pH and/or low DO values are due to natural conditions and justify a reclassification of a stream or stream segment as Class VII, Swamp Water.

If velocity is low or if slope is low (<0.50%) AND
If wetlands are present along stream reach AND
If no point sources or only point sources with minimal impact on DO and pH AND
If nutrients are < typical background
❖ average (= assessment period mean) nitrate less than 0.6 mg/L
❖ average total nitrogen (TN) less than 1.0 mg/L, and
❖ average total phosphorus (TP) are less than 0.1 mg/L AND
For DO: If seasonal fluctuation is normal AND
For pH: If nearby streams without wetlands meet pH criteria OR if no correlation between in-stream pH and rain pH,

THEN determine as impaired due to natural condition
→ assess as category 4C in next assessment
→ initiate WQS reclassification to Class VII Swamp Water
→ get credit under consent decree

The analysis must state the extent of the natural condition based on the criteria outlined above. A map showing land use, point sources, water quality stations and, if necessary, the delineated segment to be classified as swamp water should be included.

In cases where not all of these criteria apply, a case by case argument must be made based on the specific conditions in the watershed.

5.1 Preliminary Data Screen for Low Flow 7Q10

The 7Q10 flow of a stream is the lowest streamflow for seven consecutive days that occurs on average once every ten years. The first step for low flow 7Q10 screening is to determine the most accurate 7Q10 available. The 7Q10 flow for Totopotomoy Creek may be estimated by a drainage area ratio of the Totopotomoy Creek watershed (30.58 mi²) with the 7Q10 flow at the long-term continuous gaging station Totopotomoy Creek near Studley, VA, (USGS: 01673550), with a drainage area of 25.5 mi² and a 7Q10 of 0.39 cfs (2003). Thus the 7Q10 of the whole Totopotomoy Creek watershed is estimated at 0.47 cfs.

The DO Instantaneous Water Quality Standard applies **AT** 7Q10 flow, but **NOT** below 7Q10 flow (9 VAC 25-260-50 ***). Therefore in streams where the 7Q10 > 0.0 cfs, DO less than 4.0 mg/l and/or pH data taken below 6.0 S.U. taken at flows below 7Q10 are not water quality standard violations. However, in streams where the 7Q10 = 0.0 cfs, **ALL** DO data < 4.0 mg/l and pH < 6.0 S.U. are standard violations, even if the flow = 0 cfs when the DO and/or pH were taken.

There were no Totopotomoy Creek pH and DO data points collected on dates when Totopotomoy Creek flows were below 7Q10, therefore no datapoints were removed.

5.2 Low slope, Swamps, Wetlands or Large Forested Areas

The percent slope of Totopotomoy Creek was 0.18% slope (Table 5). This is lower than the defined low slope criteria of 0.50%. Decomposition of the large inputs of decaying vegetation from areas of forested land with swamps and heavy tree canopy throughout the watersheds increase oxygen demand and lower DO as they decay, as well as contribute to the low pH by creation of natural weak organic acids (tannic, humic and fulvic acids) during decomposition of the decaying vegetation. These are not considered anthropogenic

Natural Conditions Assessment for Totopotomoy Creek

impacts. Percent slope was not calculated for any tributaries to Totopotomoy Creek because none held pH or DO standard violations, except for station 2-XBS000.17 with 7.7% DO violations (1 of 13). This station was immediately below the dam of a residential development pond during low flow.

Table 5. Calculated percent slopes for Totopotomoy Creek.

Stream	% Slope	Upstream Elevation (Feet) at Rivermile (RM)	Downstream Elevation (Feet) at Rivermile (RM)
Totopotomoy Creek	0.18	160' at RM 16.42	10' at RM 0.73

Visual inspection of Totopotomoy Creek revealed swampy areas, some with heavy tree canopy. Decomposition of vegetative matter from large swampy areas lowers DO and pH as decay occurs. (Figures 10 - 14).

Figure 10. Totopotomoy Creek, Rt. 615, 8-TPT006.97, Upstream.



Figure 11. Totopotomoy Creek, Rt. 643, 8-TPT009.17, Downstream.

Natural Conditions Assessment for Totopotomoy Creek



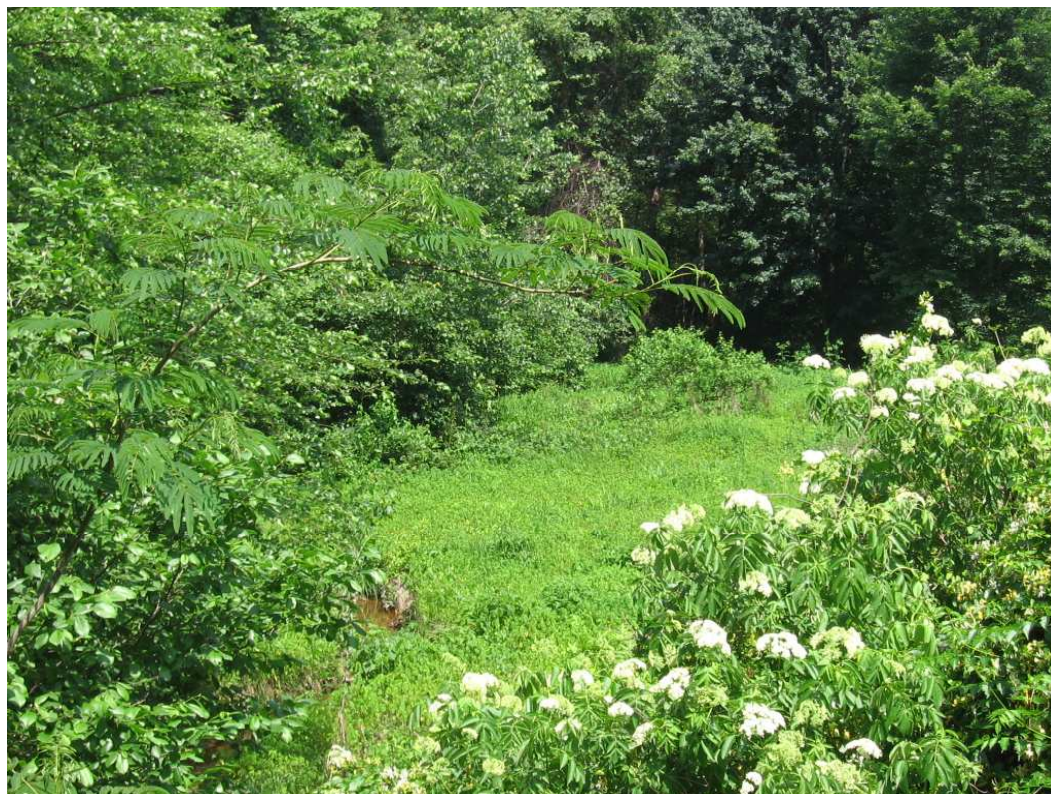
Figure 12. Totopotomoy Creek at RR culverts above Cool Springs Road, RM 013.74, Upstream.



Figure 13. Totopotomoy Creek at Stephens Manor Drive, 8-TPT015.04, Downstream.



Figure 14. Totopotomoy Creek at Milestone Drive, 8-TPT016.30, Upstream.



5.3 Instream Nutrients

The VADEQ collected nutrient data from the original listing station 8-TPT004.37 (February 1999 to December 2011, Table 6). The average total nitrogen (TN), nitrate and total phosphorus (TP) concentrations are below the USGS (1999) national background nutrient concentrations in streams from undeveloped areas with levels of TN < 1.0 mg/l, nitrate < 0.6 mg/l and TP < 0.1 mg/l. These low nutrient levels are not indicative of human impact.

Table 6. Instream Nutrients of Totopotomoy Creek 8-TPT004.37.

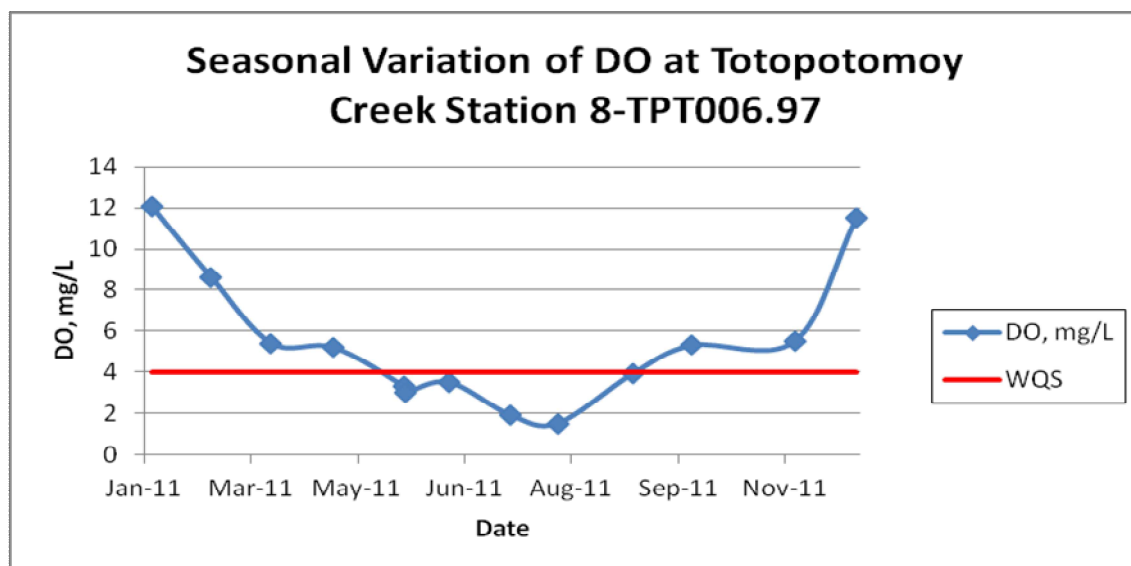
Parameter	Average Conc.	Number
Total Phosphorus	0.071 mg/l	(n=50)
Orthophosphorus	0.038 mg/l	(n=38)
Total Kjeldahl Nitrogen	0.505 mg/l	(n=38)
Ammonia as N	0.037 mg/l	(n=44)
Nitrate as N	0.451 mg/l	(n=38)
Nitrite as N	0.008 mg/l	(n=38)
TN (TKN + NO₃ + NO₂)	0.918 mg/l	(n=50)
Nitrite + Nitrate, Total as N	0.449 mg/l	(n=44)

5.4 Natural Seasonal DO Fluctuation

The 2009 DO data collected at the Totopotomoy Creek original listing station 8-MNQ004.19 were graphed to demonstrate the natural seasonal DO fluctuation due to the inverse relationship between water temperature

and DO. DO is high in the winter months while water temperatures are low, and low in the summer months when water temperatures are high. This is depicted in Figure 15.

Figure 15. Seasonal DO Variation at Totopotomoy Creek at Rt. 615, January – December 2011.



5.5 Impact from Point Source Dischargers and Land Use

There are no active permitted point source dischargers in the Totopotomoy Creek watershed.

The watershed is approximately 19570 acres (30.58 mi²) in size and is predominately forested (47 percent). Agriculture comprises 22 percent of the watershed, with 15 percent cropland and 7 percent pasture/hayland. Urban areas compose approximately 18 percent of the land base, located mostly in the headwaters. The remaining 13 percent of the watershed is comprised of 4 percent other grasses and 9 percent wetlands and open water. There are large areas of wetlands in the lower half of the watershed, and also in large pockets in the upper more urban portion of the watershed. Land use was not considered to have significantly impacted the swampwater conditions of Totopotomoy Creek.

6. CONCLUSION

The following decision process is proposed for determining whether low DO values are due to natural conditions:

If slope is low (<0.50) AND
 If wetlands or large areas of forested land are present along stream reach AND
 If no point sources or point sources with minimal impact on DO AND
 If nutrients are < typical background
 ❖ average (= assessment period mean) nitrate less than 0.6 mg/L
 ❖ average total nitrogen (TN) less than 1.0 mg/L, and
 ❖ average total phosphorus (TP) are equal to or less than 0.1 mg/L AND
 If nearby streams without wetlands meet DO criteria,

THEN determine as impaired due to natural condition

Natural Conditions Assessment for Totopotomoy Creek

- assess as category 4C in next assessment
- initiate WQS reclassification to Class VII Swamp Water
- get credit under consent decree

This study was initiated because of a pH impairment identified in DEQ ambient monitoring in Totopotomoy Creek. In addition, violations of the DO water quality standard were identified during data collection for this report.

There were no Totopotomoy Creek pH and DO data points collected on dates when Totopotomoy Creek flows were below 7Q10, therefore no datapoints were removed.

The percent slope of Totopotomoy Creek was 0.18% slope. This is lower than the defined low slope criteria of 0.50%. Decomposition of the large inputs of decaying vegetation from areas of forested land with swamps and heavy tree canopy throughout the watersheds increase oxygen demand and lower DO as they decay, as well as contribute to the low pH by creation of natural weak organic acids (tannic, humic and fulvic acids) during decomposition of the decaying vegetation. These are not considered anthropogenic impacts. Percent slope was not calculated for any tributaries to Totopotomoy Creek because none held pH or DO standard violations, except for station 2-XBS000.17 with 7.7% DO violations (1 of 13). This station was immediately below the dam of a residential development pond and the violation was obtained during low flow.

The average total nitrogen (TN), nitrate and total phosphorus (TP) concentrations are below the USGS (1999) national background nutrient concentrations in streams from undeveloped areas with levels of TN < 1.0 mg/l, nitrate < 0.6 mg/l and TP < 0.1 mg/l. These low nutrient levels are not indicative of human impact.

Totopotomoy Creek exhibits natural seasonal DO fluctuation due to the inverse relationship between water temperature and DO.

There are no active permitted point source dischargers in the Totopotomoy Creek watershed.

The watershed is approximately 19570 acres (30.58 mi²) in size and is predominately forested (47 percent). Agriculture comprises 22 percent of the watershed, with 15 percent cropland and 7 percent pasture/hayland. Urban areas compose approximately 18 percent of the land base, located mostly in the headwaters. The remaining 13 percent of the watershed is comprised of 4 percent other grasses and 9 percent wetlands and open water. There are large areas of wetlands in the lower half of the watershed, and also in large pockets in the upper more urban portion of the watershed. Land use was not considered to have significantly impacted the swampwater conditions of Totopotomoy Creek.

Based on the above information, a change in the water quality standards classification to Class VII Swampwater due to natural conditions, rather than a TMDL, is indicated for the mainstem of Totopotomoy Creek located in waterbody identification codes (WBID) VAP-F13R, for a total of 17.61 rivermiles. Even though there were two stations that did not have standard violations in the upper half of the watershed, DEQ decided to include this 3 mile segment in the Class VII designation because the lowest pH was at the standard, and the lowest DO was only 0.3 mg/l above the DO standard. This 3 mile segment probably experiences pH and DO below the water quality standards. If there is a 305(b)/303(d) assessment prior to the reclassification, Totopotomoy Creek will be assessed as Category 4C, Impaired due to natural condition, no TMDL needed.

DEQ performed the assessment of the Totopotomoy Creek low DO and low pH natural condition in lieu of a TMDL. Therefore neither a TMDL Technical Advisory Committee (TAC) meeting nor a public meeting was involved. Public participation will occur during the next water quality standards triennial review process.

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